# VIRGINIA SALTWATER RECREATIONAL FISHING DEVELOPMENT FUND SUMMARY PROJECT APPLICATION\*

NAME AND ADDRESS OF APPLICANT:	PROJECT LEADER (name, phone, e-mail):
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PRIORITY AREA OF CONCERN:	PROJECT LOCATION:
Research and Data Collection	Virginian Continental Shelf
DECORIDENCE TITLE OF DDG IFOT	

## **DESCRIPTIVE TITLE OF PROJECT:**

Blueline (Caulolatilus microps) and Golden (Lopholatilus chamaeleonticeps) Population Dynamics along the Virginian Continental Shelf

## **PROJECT SUMMARY:**

Blueline (*Caulolatilus microps*) and golden (*Lopholatilus chamaeleonticeps*) are two recreationally important species found along the coast of Virginia. The recreational and charter boat fishery for these species has increased dramatically recently, thus there has been pressure to increase regulation of harvest for both species. However, no population dynamics data are available for either species off the coast of Virginia, resulting in the Commission requesting programs be initiated to collect needed data. Thus, we propose, over a three-year period, collecting the biological information (age, growth, mortality, and reproductive characteristics) needed to construct an initial assessment of each species. We will provide this data to the VMRC to assist in the formulation of management regulations for tilefish.

# **EXPECTED BENEFITS:**

**Total Costs:** 

We will define the population characteristics of blueline and golden tilefish off Virginia and report our results to the VMRC as basic information needed to conduct future stock assessments and assist in formulating management policies. Population characteristics defined will include (but are not limited to) age structure, growth rates, fishing and natural mortalities rates, and reproductive characters. As we did for sheepshead, we will provide VMRC with a Fisheries Management Plan for tilefish. This will ensure that the sustainable harvest of tilefish off Virginia will continue, allowing for the continued growth of the fishery and the associated economic benefits of the fishery. In addition, the project will serve as a continued avenue through which recreational anglers can actively participate in the collection of data of interest to them and participate in the development of regulations.

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COSTS:				
VMRC Funding:	\$72,768			
Recipient Funding:	\$14,554			
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Detailed budget must be included with proposal.

\$87,322

Updated 11/12/08

# **Budget**

	Salary & Benefits
Faculty Salary	\$12,060
Casual Employees	\$20,000
Fringe Benefits	\$5,624
	General Expenses
Supplies	\$955
Postage	\$300
Telephone/Fax	\$500
Books/Publications	\$500
Printing	\$500
Charter Boat Hire	\$13,000
Travel	\$3,175
Histology	\$1,600
	<b>Indirect Costs</b>
Indirect Costs	\$14,554
	<u>Totals</u>
Direct Costs	\$58,214
Indirect Costs	\$14,554
Project Costs	\$72,768

## **Budget Justification**

Personnel costs: We have found that for a project such as this one, that a graduate student is more cost-effective than is a technician. Because the students use the project as part of their thesis, they are able to provide more commitment to the project's success at reduced cost. The student will collect samples, process them, and conduct data analysis. Dr. Jones will oversee the project, coordinate sample collections, and assist in data analysis. Dr. Jones will be providing her expertise with population dynamics and statistical issues, is requesting one-month direct payment for each year.

We will subcontract the Louisiana State University Department of Pathobiological Sciences to prepare fish reproductive organs for reproductive analysis. We have had a subcontract with this company before on a previous project. The cost is \$6 per slide.

We are planning to hire charter boats to collect fish samples bi-weekly for us when sample sizes are insufficient from both recreational and commercial fisheries. While we foresee contacting charter boat captains randomly, looking at current charter boat rates we estimate it will cost approximately \$13,000 to under take this sampling.

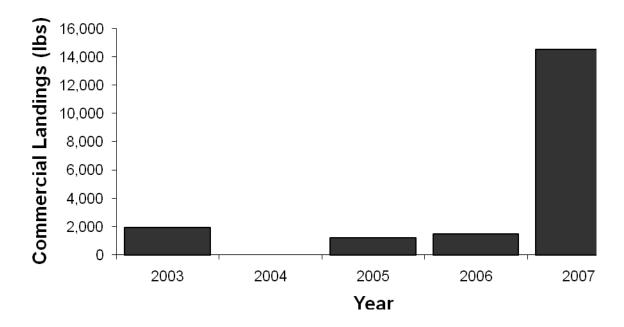
Travel costs consist of two parts. 1) Sample collection: We estimate traveling 4400 miles per year around Chesapeake Bay to collect at a mileage compensation of \$0.55 per mile. Meeting attendance: To update our knowledge of tilefish population dynamics and related topics, we are requesting \$750 to attend academic meetings during each year of the study.

Indirect costs, at \$14,554, represent 25% of the total direct costs of the project as mandated by the VMRC-RFAB proposal guidelines. Old Dominion University has a federally negotiated indirect cost rate of 50% of the direct costs. Therefore, Old Dominion University will assume responsibility for the unrecoverable indirect costs to the University, at a rate of \$14,554.

The remainder of funds goes to sample collection, processing supplies, and information exchange with local communities and organizations, such as fish clubs. We are requesting \$500 to publish the results to the public and other scientists.

We present the year one budget here. We anticipate that year two and three will be the same. Based on our experience conducting such studies, we anticipate that we will need three years of collections to obtain fully representative samples of tilefish and, thus to obtain stable parameter estimates of the population's characteristics. One of the difficulties that we anticipate is in obtaining enough near-spawning gonads to make estimates of fecundity at age and spawning stock characteristics.

# **Figures**



**Figure 1:** Annual total commercial landings of blueline tilefish (*Caulolatilus microps*) off Virginia from 2003-2007. Landings are the weight of fish landed in pounds.

# Blueline (Caulolatilus microps) and Golden (Lopholatilus chamaeleonticeps) Population Dynamics along the Virginian Continental Shelf

Proposal for Consideration by the Virginia Recreational Fishing Advisory Board

Joseph C. Ballenger and Cynthia M. Jones Center for Quantitative Fisheries Ecology Old Dominion University

# Summary for the Recreational Fishery Advisory Board

As of 2006, national law requires the completion of stock assessments for all species recreationally and commercially harvested in waters of the United States. Thus, fisheries agencies are required to assess the status off all species, whether data are available regarding a species or not. Further, when data is scarce for a particular species, mangers are required to exhibit more caution when developing management regulations. Thus, often more conservative regulations are instigated than would have been if scientific data had been available. This translates into reduced bag limits or size limits, increased gear restrictions or additional harvest restrictions on both recreational and commercial fisheries. For these reasons, the state of Virginia and its recreational anglers need to collect biological and fisheries information from data poor fisheries so that excessively restrictive regulations are not imposed.

Beginning in 2006, the Center for Quantitative Fisheries Ecology (CQFE) began the process of collecting this data from the sheepshead (*Archosargus probatocephalus*) population of the Chesapeake Bay, a species for which needed data was not available. Over a three-year period, we obtained age, growth, mortality, and reproductive data from the recreational fishery, provided this data to recreational anglers and the Virginia Marine Resource Commission (VMRC), and constructed an assessment of the population that was presented to the VMRC. Further, we worked with local anglers, anglers clubs, marinas, and other interested parties to inform anglers why this data is needed, how recreational anglers could benefit from this research, and what local anglers could do to insure the continued success of the sheepshead fishery.

Two other recreationally important species for which needed data are lacking are blueline (*Caulolatilus microps*) and golden (*Lopholatilus chamaeleonticeps*) tilefish. These species are a large component of a growing deepwater recreational fishery operating near the mouth of the Chesapeake Bay and along the Eastern Shore of Virginia. Substantial fisheries are being developed to utilize these resources, resulting in a significant economic impact to the Eastern Shore and Bay mouth regions via bait and tackle sales, fuel sales, charter boat income, etc. Thus, just as with the sheepshead population, we are proposing biological and fishery data be collected from this fishery over a three year period so that management plans can be developed that will ensure the continued growth and productivity of this resource in the future. We will use similar techniques employed in the VMRC-RFAB funded sheepshead project to encourage the involvement of anglers, collect needed data, and develop management plans for the species.

#### **Statement of Problem**

Recently, there has been a perceived increase in harvest of blueline (*Caulolatilus microps*) and golden (*Lopholatilus chamaeleonticeps*) tilefish off the coast of Virginia as commercial fisheries have expanded and recreational and charter boat fisheries have developed. While data are lacking regarding the harvest from the recreational fishery, the commercial fishery blueline tilefish landings trend supports this notion, as commercial harvest in 2007 was approximately 15,000 lbs, which represents an approximate 10-fold increase in the average harvest over the previous 6 years (Figure 1; Pers. Comm., NMFS, Fisheries Statistics Division). This increase has raised concern regarding the population status of this species as the fishery develops.

Due to the increase in harvest of tilefish and the lack of previous management of the species, on April 24, 2007 the Virginia Marine Resource Commission (VMRC) enacted the first set of regulations on the species for the Virginia area. VMRC amended those regulations on June 28, 2007 to set a recreational bag limit of 7 tilefish (combination of blueline, golden and sand tilefish) per person per day and a commercial harvest limit of 300 lbs per boat per day. However, the Commission enacted these regulations without scientific data on the populations of tilefish off Virginia, thus on March 24, 2009 the VMRC Board proposed that measures be taken to improve the data collection on blueline and golden tilefish collected from Virginia waters.

Previous studies of the dynamics of blueline or golden tilefish populations have occurred in the Gulf of Mexico, South Atlantic Bight, or northern mid-Atlantic Bight from New Jersey and further north. Managers know little about the Virginia populations, beyond the perceived increase in harvest for both blueline and golden tilefish that has occurred over the last few years, and minimal commercial harvest data obtained from the National Marine Fisheries Service. Moreover, the populations of tilefish off Virginia may be a local population governed by its unique vital rates given the limited dispersal of adults, thus making them more susceptible to local depletion. Therefore, specific data on the population dynamics of blueline and golden tilefish off Virginia must be obtained to provide a scientific base for its management.

## **Background**

Previous studies of blueline and golden tilefish have been conducted in the northern Mid-Atlantic Bight (MAB) and New England region (Grimes et al. 1988; Morse 1981; NMFS 2005) the South Atlantic Bight (SAB; Barans and Stender 1993; Erickson et al. 1985; Grossman et al. 1985; Harris et al. 2004; Katz et al. 1983; Ross and Huntsman 1982; Ross and Merriner 1983) and the Gulf of Mexico (GOM; Katz et al. 1983). These studies have provided general information about the species. Both species inhabit the outer continental shelf, with blueline tilefish ranging from Cape Charles, Virginia to Campeche, Mexico (Ross and Huntsman 1982; Ross and Merriner 1983) and golden tilefish ranging from Nova Scotia to Surinam (Grimes et al. 1988; Hightower and Grossman 1989; Katz et al. 1983). Further, each species is confined by a relatively narrow temperature tolerance, with blueline tilefish preferring slightly warmer water temperatures (15-23°C; Harris et al. 2004) than golden tilefish (9-14°C; Erickson et al. 1985; Grimes et al. 1988; Hightower and Grossman 1989). Thus, off Virginia (and in other areas), this is expected to result in spatial separation between the habitats of blueline and golden tilefish. However, in regions of suitable temperatures, adults of both species construct burrows in silt-

clay substrates or inhabit ledges or crevices around boulders and rubble piles (Grimes et al. 1982; Grossman et al. 1985; Harris et al. 2004), further limiting available habitat. Authors suggest that these fish exhibit strong site fidelity exhibited, with most fish associated with specific burrows for the majority of their life (Grimes et al. 1986; Grimes et al. 1983; Katz et al. 1983). Further, tagging studies suggest that tilefish are non-migratory as adults, with home ranges of less than 2 km with the potential for male-female pairing (Grimes et al. 1986; Grimes et al. 1988; Katz et al. 1983). To date, there is no evidence that adult tilefish migrate along the U.S. Atlantic or Gulf coast.

Grimes et al. (1988) report that golden tilefish female and male maximum ages are 35 and 26 years, respectively. For blueline tilefish, the maximum age for both males and females in the SAB is 43 years old (Harris et al. 2004). However, it is suggested that truncation of the age structure occurs rapidly with limited increases in fishing, as over a 15 year period the mean age of blueline tilefish captured in the SAB decreased from 16.9 years old from 1982-1987 to 10 years old in 1996-1999 (Harris et al. 2004). Further, the species appear to exhibit dimorphic growth between the sexes, with males attaining larger maximum lengths than females and generally being longer-at-age than females after age two along the southeastern coast of the United States (Harris et al. 2004; Ross and Huntsman 1982). As for age of sexual maturity, it appears that blueline tilefish females of the SAB attain 50% maturity by ages 4-5, while males mature slightly later at 6 years old, based on macroscopic staging of gonads (Ross and Merriner 1983). Golden tilefish females from the northern MAB and New England region were fully mature by 8-9 years of age, while males were not macroscopically assessed as mature until 7-8 years old (Grimes et al. 1988).

Historically, an increasing demand for a fish species resulted in increased management regulations on the species, concomitant with its decline in abundance. For example, the Northeast Fisheries Science Center of the National Marine Fisheries Service (NMFS) did not conduct a stock assessment of golden tilefish in the northern MAB and New England region until 1992, at which time they estimated the instantaneous fishing mortality rate (F) was at least 3 times higher than F at the maximum sustainable yield level (NMFS 2005). After an extensive literature search, we were unable to find any additional stock assessments or long-term monitoring programs for either blueline or golden tilefish in other areas. Further, both golden and blueline tilefish are recently becoming important fisheries off the coast of Virginia, requiring more information on regional or local stocks in order to establish fishery management strategies on a regional scale.

No thorough studies have been conducted and little is known about tilefish off Virginia, although there is a potential that tilefish may become more popular. The Marine Recreational Fisheries Statistical Survey (MRFSS) does not actively track the recreational harvest of blueline or golden tilefish and data is limited on the commercial harvest of tilefish off Virginia from the NMFS (Pers. Comm., NMFS, Fisheries Statistics Division). To effectively manage this species, fisheries managers must first obtain detailed scientific information regarding the populations of blueline and golden tilefish off Virginia and subsequently use this data to understand the population dynamics of the stock and to conduct a stock assessment.

Fish population characteristics such as age composition, growth and mortality rates, and reproduction parameters are primary information for recognition of putative stocks for management (Cadrin et al. 2005; Ihssen et al. 1981). Such data are necessary in a variety of stock assessment models such as ADAPT, FAST, and ASPIC, which are used by fisheries scientists to establish effective management strategies. For example, the Atlantic States Marine Fisheries Commission (ASMFC) has been using ADAPT to conduct a stock assessment of Atlantic striped bass (*Morone saxatilis*) for many years, providing fisheries managers with population dynamics information of this species. The population of this species has recovered from near depletion during the 1980s, and is considered one of the most successful examples of effective fisheries management (Richards and Rago 1999). Therefore, collecting high quality information on age composition, growth and mortality rates, and reproductive characteristics is the first and most critical step in identifying a fish stock and further in conducting an assessment of the stock, especially a near-virgin stock.

# Significance

By definition, a virgin stock is an unexploited standing stock (Gulland 1971), naturally regulated by density-dependent processes and characterized by a high proportion of old fish, slow individual growth rates, and low total mortality rates (Van den Avyle and Hayward 1999). Two signs may indicate that blueline and golden tilefish off Virginia is likely to be close to a virgin stock. First, exploitation of both species is very low compared to other regions. For example, while recreational harvest data is not available, the commercial harvest of blueline tilefish in 2007 from Virginia was 14,529 lbs, compared to North Carolina where it was 54,725 lbs. For golden tilefish, the 2007 Virginia commercial harvest was 1,278 lbs. In comparison to New Jersey (219,870 lbs; nearest state reporting harvest) this is minimal (Pers. Comm., NMFS, Fisheries Statistics Division). Second, fishermen have been continuously reporting that they catch large blueline and golden tilefish off the coast of Virginia, substantiated by the fact that the state record golden tilefish, at 56 lbs 8 oz., is only 11 oz. less than the all tackle international record and the state record blueline tilefish, at 19 lbs 14 oz, is the all tackle international record (pers. comm., VMRC). Therefore, either tilefish grow larger off Virginia than elsewhere, or mortality is so low that fish get much older and larger here.

It is very unusual to find a near-virgin stock off Virginia in 2009, and it is also unusual for stakeholders to request a study of a fish stock before it is fully exploited – such as the tilefish stock off Virginia. Taking this opportunity, we will be able to estimate an approximate natural mortality, and monitor and examine the response of the blueline and golden tilefish population as fishing pressure increases off Virginia. The information from the project will benefit Virginia recreational anglers as follows:

1) When a stock is first open to exploitation, population characteristics start to change. For example, age composition may shift from a majority of older fish to younger fish and individual growth rates may increase. By modeling the blueline and golden tilefish population off Virginia, we can examine and test a variety of modelss for its management. Proper management will lead to the sustainable exploitation of this resource by recreational anglers.

2) This study will also contribute biological, ecological, and conservation knowledge on tilefish. Previous authors report that blueline tilefish are widespread from Cape Charles, Virginia to Campeche, Mexico (Ross and Huntsman 1982; Ross and Merriner 1983) and golden tilefish range from Nova Scotia to Surinam (Grimes et al. 1988; Hightower and Grossman 1989; Katz et al. 1983). However, we have not found any studies on tilefish populations off Virginia. Knowledge of these species off Virginia will provide information needed for conservation and sustainability of this species, especially since there is potential connectivity between tilefish stocks.

## **Objectives**

This study would be the first to evaluate blueline and golden tilefish population dynamics off the coast of Virginia. This data, integrated with data collected on blueline and golden tilefish in other regions, could help us answer several questions of interest and establish a baseline of data for a stock assessment of these species off the coast of Virginia. Our specific objectives are to: 1) examine the age composition of blueline and golden tilefish off Virginia, 2) estimate their annual growth rates, 3) estimate annual fishing and natural mortality rates, and 4) evaluate their reproductive characteristics. With the information above, we will be able to construct an assessment of the status of the stock off the coast of Virginia and recommend management measures that would sustain the recreational angling experiences.

## **Hypotheses**

H0<sub>1</sub>: Age composition of blueline and golden tilefish off Virginia is the same as for the South Atlantic Bight (SAB), Gulf of Mexico (GOM), and northern mid-Atlantic Bight (MAB). Ha<sub>1</sub>: Offshore Virginia population is composed of older/younger fish.

H0<sub>2</sub>: Size-at-age is the same for blueline and golden tilefish off Virginia, the SAB, the GOM, and the MAB.

Ha<sub>2</sub>: Offshore Virginia population exhibits different size-at-age relationship than other areas.

H0<sub>3</sub>: Mortality is the same for blueline and golden tilefish off Virginia, the SAB, the GOM, and the MAB.

Ha<sub>3</sub>: Mortality rates differ among the offshore Virginia tilefish population and other regions.

H0<sub>4</sub>: The reproductive characteristics of blueline and golden tilefish found off Virginia is the same as the reproductive characteristics of tilefish found in the SAB, the GOM, and the MAB. Ha<sub>4</sub>: Virginia tilefish exhibit different reproductive characteristics than tilefish studied in other regions.

#### Methods

## Fieldwork

Recent evidence suggests that the majority of blueline and golden tilefish landed in Virginia have derived from either the recreational fishery or charter and party boat fishery. However, it is

possible that fish sizes vary spatially and between the recreational and commercial fisheries. To obtain a complete range of sizes, it will be necessary to sample tilefish from both fisheries sectors. We anticipate that anglers will provide some of the samples needed for age and fecundity estimates, but these samples may have to be supplemented by fishery-cooperative or fishery-independent sampling if we cannot obtain gonads in "fresh" condition. Commercial sampling will provide a broader range of sizes to determine age composition than can be obtained solely from angling.

## Recreational Sampling:

To sample the recreational fishery, we will ask anglers to donate blueline and golden tilefish through a cooler system originally designed by CQFE staff to sample the sheepshead (*Archosargus probatocephalus*) population of Chesapeake Bay. This system will rely on the strategic placement of coolers at local marinas where anglers commonly land tilefish throughout the year. Anglers will place collected tilefish on ice and notify us to collect the fish from them. We will notify anglers of this program by contacting angling clubs, utilizing angler message boards, and through appearances on fishing shows as we did for sheepshead. We anticipate that this will allow us to collect most of the reproductive organs we will need for fecundity estimates.

Further, tilefish collected via the VMRC Marine Sportfish Collection Freezer program will supplement samples from this system. In 2007, the VMRC collected 47 blueline tilefish from this program and we anticipate that these numbers will increase, as that was the first year of the program.

# **Commercial Sampling:**

Blueline and golden tilefish are caught commercially in other regions via bottom long line gear and bottom trawls. Though it does not appear that there is a directed commercial fishery for tilefish in the Virginia region at this time, any tilefish landed as bycatch of other commercial fisheries at Virginia ports that the VMRC intercept during their daily sampling of the commercial sector could be purchased if recreational samples are proving difficult to obtain.

## Fishery Independent Sampling:

If the number of samples is insufficient from the recreational sector, we will use charter boats to collect blueline and golden tilefish. Charter boat captains with experience fishing for tilefish will be randomly selected for a full day of fishing off the Virginia coast. This will supplement the number of samples needed for this study.

#### Lah work

Once fish are collected, they will be brought to the Center for Quantitative Fisheries Ecology (CQFE) at Old Dominion University where they will be measured, weighed, and otoliths and gonads removed.

## Otolith Processing:

We will use a "bake and thin-section" technique to process blueline and golden tilefish otoliths for age determination developed by the CQFE. The otolith will be secured to a microscope slide, and sectioned using a Buehler Isomet low-speed saw equipped with two Norton diamond

wafering blades separated by a 0.4 mm stainless steel spacer, positioned so that the wafering blades straddles the focus. Post sectioning, we will place the otolith section into a ceramic "Coors" spot plate well and bake it in a Thermolyne 1400 furnace at 400°C. Baking time will be dependent on otolith size and gauged by color, with a light caramel color desired. We will place the baked thin-section on a labeled glass slide and cover it with a thin layer of Flo-texx mounting medium.

# **Gonad Processing:**

Histological sectioning of gonads will follow the methods of Ross and Merriner (1983) and Grimes et al. (1988) for blueline and golden tilefish, respectively. Both species gonads will be preserved in 10% buffered formalin and histological sections will be stained using standard histological staining (haemotoxylin and eosin; H&E) techniques. Each gonad will be cut in half and three replicate 1 cm<sup>3</sup> gonadal samples will be taken from each fish, making sure that samples are taken from the tunica to the lumen to assure representative parts of gonadal material are sampled.

## Age Determination:

Otoliths are read under a microscope using polarized light and an image analysis system. Procedures to establish quality assurance and reliability of age readings are incorporated into the CQFE laboratory protocols. We measure precision between age readings done by all readers so that we have consistency. CQFE staff read otoliths double-blind (with no knowledge of time or place of capture or length of fish). A randomly selected subsample is read twice by the same reader and by another reader to test consistency among and between readers (Campana et al. 1995; DeVries and Frie 1996). We use a symmetry test (Bowker 1948) to measure precision and to observe tendencies to over- or underestimate age. Because it is also important to maintain consistency in age readings between years, we insert a sample of hard parts read in prior years among currently collected samples following double-blind procedures to test year-to-year consistency in ageing (Campana et al. 1995). We test for potential differences with repeated-measures ANOVA. Such vigilance keeps our age readings consistent and reliable from year to year.

## Age Composition and Growth:

To evaluate growth, observed length-at-age data will be fitted to a von Bertalanffy Growth function (Ricker 1975; von Bertalanffy 1938), by non-linear least square regression,

$$L(t) = L_{\infty} (1 - e^{-k(t-t_0)})$$

where L(t) is the total length at time t and t is the age of the fish in years. The model includes three parameters estimated via non-linear least squares regression, those being  $L_{\infty}$  (mean maximum fork length), k (Brody growth coefficient), and  $t_{\overline{0}}$  (hypothetical age when length equals zero).

We will use likelihood ratio tests (Cerrato 1990; Kimura 1980) to determine if differences exist between von Bertalanffy parameter estimates between sexes and years for mean total length-atage data:

$$\chi_{v}^{2} = -N*\ln\left(\frac{SSR_{\Omega}}{SSR_{\omega}}\right)$$

where v is the degrees of freedom (equals the number of constraints placed upon the fit), N is the total number of age groups from both curves combined,  $SSR_{\Omega}$  is the total sum of squared residuals derived from fitting both curves separately and  $SSR_{\omega}$  is the total sum of squared residuals derived from fitting the curves with one hypothesized constraints (i.e.  $L_{\infty}$  are the same, etc.).

To determine the age distribution of the blueline and golden tilefish populations off Virginia, we will use the fish we measure and age to construct an age-length key. We can use the key to convert catch-at-size data into catch-at-age data. The keys specify the probability that fish of a given size belong to one of several age groups.

## Mortality:

We will use a weighted catch-curve analysis (Slipke and Maceina 2002) to estimate the instantaneous rate of total mortality (Z). For this method, we plot the logarithms of number-atage versus age data. If missing age classes occur in the data, then one must be added to all number-at-age data because the natural log of zero cannot be computed. This generally results in a curve that has a steeply ascending left limb, a dome-shaped upper portion, and a long, descending right limb, which is nearly straight. We fit a weighted linear regression, which deflates the importance of rare and older fish when computing the slope of a catch-curve regression, to the descending right limb, which represents age classes that are fully recruited to the fishery. The slope (±SE) of this weighted linear regression provides a point estimate (± SE) of the negative instantaneous total mortality rate (-Z). Detailed descriptions of this procedure are provided in Steele and Torrie (1980), Montgomery and Peck (1982) and Fruend and Littell (1991).

To estimate natural mortality, we will use two methods based on the longevity of blueline and golden tilefish off Virginia. The first is based on a linear regression model derived from empirical data collected on 84 fish stocks representing 53 species that were either very lightly exploited or unexploited populations (Hoenig 1983). By assuming the instantaneous fishing mortality rate (F) was negligible, thus equating the observed Z to the instantaneous natural mortality rate (M), Hoenig was able to develop a predictive relationship between maximum ages ( $t_{max}$ ) and M:

$$\ln(M) = 1.46 - 1.01 * \ln(t_{max})$$

where  $\vec{M}$  is an estimate of the instantaneous natural mortality rate (Hoenig 1983).

The second method to estimate natural mortality consists of determining the value of M such that 100(P)% of the animals in the stock survive to the age  $t_{max}$  such that (Quinn and Deriso 1999):

$$\tilde{M} = \frac{-\ln(P)}{t_{max}}.$$

Hoenig (1983) assumed that the proportion, P, that attained the maxi mum age is 0.01, while other authors prefer the assumption that the proportion surviving to  $t_{max}$  is 0.05 (Shepard and Breen 1992).

## Reproduction Status

Sex and gonadal stage of tilefish will be determined via macroscopic gonadal staging and microscopic histological examination according to methods developed by Ross and Merriner (1983) and Grimes et al. (1988) for blueline and golden tilefish, respectively. These papers report the ova stages observed in blueline tilefish correspond to those described by Moe (1969) for red grouper, *Epinephelus morio*, while spermatogenic stages are analogous to those described for red grouper (Moe 1969) and *Tilapia* spp. (Hyder 1969).

Determination of reproductive strategy (batch vs. total spawner) is straightforward using histological samples of gonads. Batch spawners possess several developmental stages of oocytes at any given time while total spawners do not. In the simplest case, all developmental stages (excluding hydrate oocytes) of oocytes are present within one ovary. Similarly, group synchronous spawners would all have at least two distinct stages occurring simultaneously while asynchronous development is characterized by oocytes representing all stages of development and constant oocyte recruitment. Several authors have investigated the reproductive strategy of blueline and golden (Erickson et al. 1985; Grimes et al. 1988; Harris et al. 2004; Ross and Merriner 1983). Grimes et al. (1988) indicated that golden tilefish of the northern mid-Atlantic Bight are batch spawners. Erickson et al. (1985) suggests the same for golden tilefish of the South Atlantic Bight, while Ross and Merriner (1983) and Harris et al. (2004) suggest blueline tilefish are batch spawners in the South Atlantic Bight. We anticipate that tilefish off Virginia will follow this pattern. If so, we must estimate both batch fecundity throughout the season and estimate the number of batches in a season.

Batch fecundity can be defined as the number of ripened oocytes in the ovary immediately prior to spawning (Bagenal and Braum 1978). We will use two methods to estimate fecundity. For hydrated specimens, we will use the hydrated oocyte method (Hunter et al. 1985). In this method, a sub-sample of the gonad is weighed to the nearest 0.1 mg. Researchers count the number of hydrated oocytes and the product of the hydrated count and the weight of the gonads for both lobes provides an estimate of batch fecundity. For specimens that are fully matured but not hydrated, we will employ an oocyte size-frequency distribution method (Hunter et al. 1985; MacGregor 1957). With this method, the most advanced modal group of oocyte size classes is determined visually by constructing a size-frequency distribution of the oocytes. The total number of oocytes that constitute the most advanced mode is assumed to be the spawning batch. This method yields similar results as the hydrated method if highly advanced oocytes are used (Hunter and Goldberg 1980; Laroche and Richardson 1980).

Typically, determining the number of batches in a season is difficult. However, by sampling frequently over the course of the spawning season we can estimate the number of batches by examining the proportion of the population with post-ovulatory follicles present (evidence of recent spawning). The inverse of this proportion gives the average time between batches (Hunter and Goldberg 1980). For example, if 30% of the population has post-ovulatory follicles then the average interval between batches is 3 days. Thus, we can estimate the age-specific, batch

fecundity and by summing over the spawning season we can determine total fecundity for the population using characteristics from the sampled population.

# **Communicating with the Angling Community**

We will use the CQFE website (www.odu.edu/fish) to make all our data available to anglers who donate fish carcasses and who are interested in this project. Anglers who donate fish can learn the fish's age and reproductive status from the website. We have found that this was an excellent way to communicate with anglers in our sheepshead project.

# **Expected Results**

## Fisheries Management

Population characteristics of blueline and golden tilefish off Virginia will be defined and reported to VMRC as basic information needed to conduct future stock assessments and assist in formulating management policies. As we did for sheepshead, we will provide VMRC with a Fisheries Management Plan for tilefish.

## Academic Contributions

Two manuscripts will be submitted to peer-reviewed journals, one regarding blueline and golden tilefish growth and mortality off the coast of Virginia, the other about tilefish reproduction characteristics off the cost of Virginia.

## **Timeline**

## Year One

- 1) Finalize logistics with volunteer fishing groups (e.g. charter boat captains) for collecting tilefish
- 2) Collect tilefish from recreational anglers
- 3) Begin bi-weekly fishery-independent sampling through hire of charter boat captains
- 4) Contact commercial fishers in Virginia to arrange the purchase of tilefish bycatch harvested
- 5) Process ovary samples for batch fecundity
- 6) Process blueline and golden tilefish otoliths for age and growth analysis
- 7) Ovarian samples are sent for histological preparation
- 8) Ageing using otoliths

#### Year Two

- 1) Continue to receive samples from recreational anglers
- 2) Continue bi-weekly fishery-independent sampling with charter boat captains
- 3) Continue sampling to collect commercially harvested fish
- 4) Process ovary samples for batch fecundity estimation and histological preparation
- 5) Process blueline and golden tilefish otoliths for age and growth analysis

- 6) Ovarian samples are sent for histological preparation
- 7) Ageing using otoliths
- 8) Preliminary fecundity estimates for tilefish off Virginia
- 9) Create a yield per recruit model to determine biological reference points and report the findings to the VMRC and the VMRC Recreational Fishery Advisory Board (RFAB)

#### Year Three

- 1) Continue to receive samples from recreational anglers
- 2) Continue bi-weekly fishery-independent sampling with charter boat captains
- 3) Continue sampling to collect commercially harvested fish
- 4) Process ovary samples for batch fecundity estimation and histological preparation
- 5) Process blueline and golden tilefish otoliths for age and growth analysis
- 6) Ovarian samples are sent for histological preparation
- 7) Ageing using otoliths
- 8) Preliminary fecundity estimates for tilefish off Virginia
- 9) Create a yield per recruit model to determine biological reference points and report the findings to the VMRC and the VMRC Recreational Fishery Advisory Board (RFAB)
- 10) Final data analysis
- 11) Prepare and submit the final project report to the VMRC and the VMRC-RFAB
- 12) Prepare two manuscripts

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## **Laboratory Facilities**

In September 1997, the VMRC established the Age & Growth Laboratory at the CQFE at ODU to provide routine ageing of Virginia's marine finfish catches. The laboratory provides VMRC with the fundamental demographic data necessary for fisheries management. It is the mandate of this laboratory to help ensure Virginia's fish stocks remain a viable resource for future generations. To safeguard this resource, the Age & Growth Laboratory has established criteria that not only best suit the individual species, but also are consistent with other aging facilities to allow for coast-wide data exchange. Currently the lab is responsible for aging 14 species of marine finfish. Bony structures presently being used to age fish include otoliths, scales and opercula. However, we are examining additional hard (bony) structures, including pectoral fin rays, dorsal spines, anal spines, pelvic spines and vertebrae, for use as alternative aging structures.